METHOD FOR APPLYING PAINTS OR VARNISHES

[0001] The invention relates to a method (and device) for the application of paints or varnishes in order to color object faces, in particular architectural object faces.

[0002] The invention in particular relates to a method as well as device for the economical application of paints or varnishes on the faces of objects like buildings and public and civil engineering works according to an image template. The surfaces can be for example inside or outside walls, floors and ceilings of residential or industrial buildings, but also surfaces out of concrete of bridges, tunnels and road construction works or walls for noise protection, blinds or fixations or related surfaces.

[0003] Today the afore mentioned object faces are without exception painted manually by paintbrush or paint roller or are color-sprayed using an airgun. The paint serves for sealing the wall on the one hand, but it is also utilized for decoration purposes. If image themes are to be applied onto the mentioned surfaces by paint the paint application can only be performed by talented craftspeople or artists, a process which is normally tedious and thus expensive. Often there can be an essential dicrepancy between the expectations of the client and the finalized image. A pure technical method would be desirable, which makes it possible to apply an image theme according to a template onto the mentioned surfaces by using paints or varnishes without requiring artistic skills and which additionally ensures a high quality of image recording. So it is obvious, that a method and a device do not exist, which allow for example to apply a color design according to a digital template onto surfaces of architectural objects like buildings and public and civil engineering works.

[0004] Based on that fact it is the task of the invention to create a simple and reliable method to apply paints or varnishes onto foremost architectural object surfaces, with the purpose to apply an arbitrary color design.

[0005] The technical solution is characterized as in claim 1.

[0006] By this a fast and reliable method is created, by which it is possible, to apply existing digital image data onto arbitrary faces of objects like buildings and public and civil engineering works. The herewith claimed method is suited to account for the individual features of the surfaces like the geometry and the base layer, as well as the features of the face, which complicate the work operation like protrusions, balconies, doors, windows, sills, branches, cornices, scaffolds or constructural elements, but also regions, in which a color application is not desired, because otherwise a complete paint application with high quality is not possible. In spite of the mentioned features, which perturbate the work operation the system is able to apply paint within a tolerance of centimeters od millimeters over very large distances.

[0007] The method according to the invention is based on the thought to transfer the color information of every image pixel, which was previously stored into a file, to the objetct surface, by measuring the position of the paint application device continously and by applying paint after having compared the stored color information with the corresponding position of the paint application device. According to the method of the

invention in a first step the properties of the object face are recorded. In a second step the recorded properties of the object face and the image template are digitally processed and assigned to each other. In a third step the position-dependent application of the image onto the object faces is performed by use of the paint application device according to the invention.

[0008] The method according to the invention makes it possible for the first time to apply a decorative color design by a pure technical method on very large, individual shaped object faces. By recording the individual properties of the object face and digitally processing the same with the digital image template the object and the template can merge to a single entity, bevor the paint application is performed. This results in new possibilities of decoration for walls, facades or functional engineering works. Further new design possibilitires in arhitecture are created, which can be accounted for already durcing the building design. These possibilities are supported by general trend of using computer aided design and construction.

[0009] First recording of the object faces and of the positions of perturbation of the object face like doors, windows, protrusions, balconies, window sills, deposits eaves, arresters, switches, lamps and other features is performed with the help of a measurement system, which works according to functional princples which are also used within the navigation system of the paint application device. In this first step also the color properties of the base layer may be recorded electronically with the purpose of color adjustment in a later step. Also the quality of the base layer may be evaluated and may be improved by adding layers like finery or a ground layer.

[0010] After recording the individual object faces including all borders protrusions, doors, windws an areas, which may be omitted for paint application, by means of measurement technology the object data are resident within a computing device for the further processing. This computing device can be also part of the paint application device. Digital data related to the properties of the object face are also digitally precessed and assigned to each other.

[0011] For this out of the recorded geometric properties a virtal surface object is derived, where every point ot the virtual surface object is assigned a point of the real object face. By using a contactless angular oder range measurement method this can for example be done by displaying the the recorded points of the object on a screen and by interactively creating a coherent with a computer aided design-tool (CAD) by a designer. If an imaging method was used for recording the object face the recorded image can directly be defined as a surface object, where the assignment of the coordinates of the virtal surface object and the image of the real surface is given directly.

[0012] Next the digital template of the design and the virtal surface object is fitted together and optionally edited. This can be done by use of the known methods of digital image processing and CAD. For example, the image can be zoomed in size, copied and overlayed by text, rotated, distortet, undistorted, supplemented by further graphic data and the color tone can be modified and adapted. For this for example a color measurement during the recording of the object face is advisable.

[0013] After all for every point of the virtual surface object the corresponding color value is stored.

[0014] It can be desirable, to keep defined points or regions free from color, for example in case of an existng decorative ground layer or an existing structure, but also when functional elements are existing, which may not be coverd by paint. The

mentioned regions can be marked as cut-out within the digital image processing, effecting, that no paint will be applied.

[0015] Optional, in case of an imaging-based recording of the object face, the information recorded can be included in the step of image processing. So, for example spots on the object face or regions with different ground color may be additionally recorded. In these cases the recorded picture of the surface face can be included in the image processing, either to compensate spots or to amplify volitional features color. Spot compensation can, for example, be done by adding the inverted recorded image containing the spots to the digital template to receive a corrected image.

[0016] The digital data representing the composition of the object face and the image template are digitally processed and assigend to each other in the way, that a virtual surface object is derived from the recorded geometrical properties and every point of the virtual surface object is assosiated to to point of the real surface, that further the digital design template is implemented into the virtual surface object and edited if necessary and, that finally the color value for every point of the virtual surface object is stored. Geometrical editing describes the modification of the digital design template within the virtual surface object, for example by moving, rezising or distorting the template. Colour editing desrcribes the modification of the digital design template within the virtual surface object, by modifying the color values of the template. With respect to the object face digital edition is understood as the reported data representing the color properties of the object face are additionally accounted to calculate the color values of the points within the virtual surface object. The color value of the points of the virtual surface object is defined, by substracting at every point the color value of the modified or unchanged color value of the real object face from the nun-edited and edited color-value of the digital design template, yielding in a compensation of blotches.

[0017] The following shall explain the operating sequence of the paint application method:

When the movable paint application device is moved over the object face, the position measurement system continuously supplies the actual position of the paint application device. Due to the known position of each single paint application element within the design of the device and the known position of the paint application device relative to the object face the position of every paint application element is computed in realtime. The control unit then fetches the color values from the surface object, which is stored in the system memory as assigned to the position-coordinates, and sends in real time commands for color application to the individual paint nozzles. Normally the digital resolution of the stored surface object differs from the real resolution of paint application device. In this case a resolution correcting step can be performed in a batch step prior to the paint application or during paint application by realtime-interpolation. Once a virtual color pixel has been fully applied onto the object face the pixel is, for example, assigned the attribute “done”, switched passive or the color value is pasted by a value, which does not result in a color application. By this an unintended multiple color application at a single point can be avoided.

[0018] At least once every point of object face has to be passed over by the application head during paint application. Thanks to the integrated position calculation a countinous motion of the device is not required, because at any time the device compares the actual position with respect to the stored image to be recorded

and commands for paint application are only launched, if paint has to be applied at that position, and has not already been finalized by an earlier stroke of the device.

[0019] The movement of the paint application device must not necessarily be performed continously. The position measurement systems allow for a comparison of the actual position of the device with the target position of any applied pixel of the image. By this it is also possible to paint non-coherent regions.

[0020] The position measurement of the paint application device can be done in multiple ways by use of position measurement systems. These may be devided into two cathegories:

[0021] The systems herein referred to as first measurement system measure the position of movable components in relation to fixed landmarks, herein called satellites, also as part as of the first measurement system. The movable parts of the first measurement system can be included into the paint application device. It is a characteristic of the first measurement system, that there has to be an intervisibility between the satellites and the moving components. Intervisibility can be often disturbed, for example by scaffoldings, cornices or branches, and position sensing is interrupted.

[0022] The systems herein referred to as second measurement system measure the movement of the paint application device for example by sensors, which are included in the paint application device and which do not utilize fixed landmarks. These are for example linear and rotational acceleration sensors, rotational rate sensors, velocity sensors, magnetometers, inclinometers, and imaging sensors, which inspect a small area of the object face, from which the motion is calculated for example by correlation methods. The measurement methods of the second measurement system are further characterized in being fast, being not able to sense an absolute position and being sensitiv to drift.

[0023] The accuracy requirements of the position sensing are high: When assuming an absolute image resulution of 0.5 mm in a range of 10 meters a realtive accuracy of 50 ppm is resulting. In parallel it is required, that the paint application device can be moved sufficiantly fast at any point of the object face and thereby being always able to measure its position with the necessary rate.

[0024] Some measurement methods according to the first measurement system can only provide a low measurement rate. So, position information is not permanently available, also and especially in case of disturbed intervisibility between satellites and the movable components. On the other hand the much faster methods as used in the second measurement system are suited to overtake navigation for short time periods. It is obvious, that combining both allows for covering the object face completely on the one hand and allows for a high feed rate on the other hand.

[0025] Assuming a paint application device operated manually by an operator and based on a combaination of a first and second measurement system the operation sequence can proceed as follows:

The operator brings the paint application device into contact with the object surface by pressing it against the surface. When the color application is started by a command from the operator, it is checked first if position informations are available from the first measurement system. For this intervisiblity has to be possile between the relevant components of the first measurements system. If not, the operator has to be informed, either by a negative message or by not providing a positive message, and the operator is instructed to move the paint application device over the surface,

until the first measurement system supplies a valid position. This position is used by the paint application control and to initialize the second measurement system. Initializing can simply mean to reset the initial conditions of the motion sensors. Now follows the computation of the position based on the available measurement data as provided from the first and the second measurement system. In this case, right after an initialization, the position calculated is identical to the position provided from the first measurement system. A positioning error is estimated and handed over to a range check routine to get a decesion, whether paint may be applied or not. If the position error exceeds an accepatance threshhold, the color application is stopped and the afore described process of finding an initial position has to be repeated. Typically, the estimated position error does not exceed the acceptance threshhold, so paint application can be performed and new position data can be read. The described cycle is running so fast, that the paint application device has already moved due to the velocity of the motion. So a position error is produced due to said motion and furthermore by the fact, that every paint application head induces a definite time delay when transporting the paint onto the surface. As a consequence the resulting position error has to be corrected for example by implementing position offsets. Practically this means, that those color values of the color – position assignment are forwarded to the color application head for paint application, which according to the color – position assignment are located ahead of the actual realtime position. The position offset generally is a function of the velocity and the acceleration. It is recommended to additionaly evaluate and check the acceleration of the device before applying paint in order to automatically prevent paint application during jerkey motions. After having applied paint, the first measurement system is checked for a valid position. A position may by invalid, if intervisibility is disturbed, as already explained above, or if the measurement rate of the first measurement system is lower than the actual cycle speed of system. If there are new data available from the first measurement system, the calculation of the actual position may be based on actual position data as well as past position data. If not, a message will be sent to the operator and the subsequent position calculation will only be based on actual measurement data from the second measurement system and past position information. In both cases the position error is evaluated and checked before issuing the paint application command. It is obvious, that when moving the paint application device far into an area, where intervisibility fails, the position error increases from cycle to cycle and finally the paint application is stopped automatically.

[0026] Based on the messages the operator is able to recognize regions, where intervisibility issues within the first measurement system occur. If he has identified an aforesaid region, he is advised to bring the paint application device into contact with the object face at a point of known position and to move the device into the said region shortest or quickest path. In case of a very large reagion, when also repeated action does not result in a paint application, the opertator is advised to mount additional landmarks of the first measurement system.

[0027] While in the majority of cases it is necessary to operate the two measurement systems in a coupled mode of operation, it may be sufficient in special cases to use color application devices with a measurement system, which is based exclusively on navigation systems. This kind of position sensing can be be sufficient, if an existing, already aged color design has to be restorated or color-refreshed or, to round out an image in corners or niches, starting from already completed parts of the image. A system of that kind for example consits of a scanning device, directed to the wall, a velocity sensor for mesurig the movement speed and an angular rte sensor with it

sensing axis perpendicular to the wall surface. The system finds its position by identifing regions which are already painted, when moving the system over the regions and recording the image.

[0028] An advantagous embodiment according to claim 2 proposes a first measurement system.

[0029] All embodiments of the first measurement system contain satellites as subcomponents, which are positioned at defined points by an operator at the beginning of the working procedure. This measurement system is further suited to form a reference coordinate system. Intervisibility is postulated between the satellites and the measurement point, which is not given in all cases. But by using a large number of satellites a high coverage of the object face is achievable. This measurement system can be used to record the properties of the object face as well as to measure the position of the paint application device. The use of a single measurement system for both purposes is not required necessarily, but advantagous for the whole operation sequence, since for the whole sequence a unique coordinate system can be used. So the measurement system records the object face and additionally the paint application device.

[0030] The position or colour information may be generated within a satellite: In this case a (realtime-) data transfer has to take place between the satellites, an optional intermediary computation unit and the paint application device. Wireless data transmission methods are especially suited for this configuration.

[0031] So the afore mentioned first measurement system serves for recording the poperties of the object face and/or for the continous recording of the position of the paint application device, and contains one or more satellites, which are located in a fixed positoin in relation to the object face. A Satellite may comprize one or more transmitters or recievers of a contactless distance or angular measurements system, further a one or more cameras, which record the object face or part of the same, further means to illuminate the object face, further a laser-source with an integrated scanning unit, further a photo-electric transducer, further means to perform a modulation or pulsing of electricak signals and means to store and/or transmit measurement data. Further the first measurement system may contain one or more transmitting or receiving components of the contactless position- or angular measurement system, which is joined with the paint application elements and/or the object face, further one or more marks, which consist of a high reflectivity compared to the housing of the paint application device and/or the object face and which emit light and/or heat, further means to perform a modulation or pulsing of electrical signals and means to store and/or transmit measurement data. A mark can contain a triple mirror.

[0032]The at least two satellites may contain at least one PSD or one camera. Further a source, which emits electromagnetic waves, can be contained in the satellites, in further components of the frst measurement system or in the paint application device. Image recording of the object face can be done by cameras contained in satellites of the first measurement system. The geometry of the object face may be preferable recorded from an image taken from at least one satellite containing at least one camera, which is sensitive in the visible or infrared range.

[0033] Further the object face may be recorded by scanning a laser beam emitted from at least one satellite over the object face in a line-by-line and/or column-by-column pattern with a defined time schedule. The light scatterd from the surface or the reflected heat can be detected by at least one camera being sensitive in the

visible or IR-range, by a photo detector or a IR-detector. Out of the measurement data and the known position of beam over time an image of the object face can be collocated.

[0034] Points of the object face in the image representation can be emphasized by attaching at least one mark to that points and recording the mark.

[0035] Modeles containing a laser source, a beam-deflection unit, a photo-electric detector as well as a control unit can be positioned at one or more far points.

[0036] The color properties of the object face can be recorded, e.g. by measuring the stray light emitted from points of the object face by using photo electric transducers. The color properties may be averaged over reagions.

[0037] The first navigation system may function accoring to an angular measurement method, whereby a source emitting electromagnetic waves is located on the paint applicatin device. Further the satellites may contain photo electric sensors, which detect the direction of incident electromagnetic waves. Further the satellites of the dirst measurement system may contain preferably at least one PSD and/or camera, while the at least one further partial system of the first navigation system emtis electromagnetic radiation of a wavelength, which can be detected by the at least one satellite.

[0038] Further the satellites may comprize at least one camera, which is positioned to record an image the object face or parts thereof as well as the paint application device or parts thereof. Featues of the paint application device are indentified within the recorded images by the help of a computation unit and the position of the paint application device is calculated from the position of the features. Images of the paint application device and of the object face or parts thereof may be taken by one or more cameras, which are sensitive in the visible or infrared band and which are positioned a fix point in a distance to the object face, that they are able to capture the object face or parts thereof. The image of the color application device and/or the object face or parts thereof can be taken from a fix point in a distance to the object face by a bundled light beam or laser beam from this point, which is scanned over the paint application device and the object face line by line and/or column by column acording to a well defined time schedule. The light or infrared radiation being back-scattered from the paint application device and/or the object face is measured by at least one camera being sensitive in the visible or infrared band, by a photo-detector or an IR-detector. From the measurement data an image of the object face and the paint application device is collocated based on the position over time of the bundled light beam or laser beam.

[0040] The fix far points preferably comprize modules, which comprize a laser source, a beam-deflection unit, a photoelectric detector as well as a control unit, the marks are preferable triple mirrors.

[0041] Preferably a continuous recording of the position of the paint application device relative to at least a part of the fix points located in a distance to the object face is performed.

[0042] According to claim 3 the measurement method is based on a contactless measurement of distance or angles. This can be performed with the help of light, infrared, electromagnetic waves or ultrasound. For the purpose of evaluating the position of the paint application device movable position measurement units are comprized within the same. To record the geometry of the object face either the paint application device or movable autarkic modules, which contain position measurement

units, can be touched with points of the object face, whereby an acknowledge command is given by the operator to store the measured data.

[0043] Satellites as well as position measurement units may work as a transmitter and/or a reciever. Elapsed time and/or angles are measured in this case between the systems.

[0044] As an example PSDs (position sensitive devices), which act as satellites, are mounted at at least two fix positions and which acquire the object face or parts thereof. With the help of PSD being equipped with a lens the direction of the focal point of incident light can be measured with extreme accuracy in the 2D or 3D domain. A LED as a light source on a movable position measurement unit, can be localized by said PSDs. The mesurement signals out of all PSDs are collected in a computation unit and the position of the movable position measurement unit is calculated out of the measured angles. In stead of PSDs cameras may be used. Cameras are also suited to measure the angle of incident light by simple measuring the position of the light dot from the LED in the image. This dot can additionally be extracted out of optional background light with the help of feature extraction methods.

[0045] When using more than one light source or also in case of a background light, wavelegth-selective methods, multiplexing methods or mudulation methods may be incorporated.

[0046] Besides the angular measurement methods the light- and laser-based distance measurement methods shall be mentioned, which are based on the measurement of elapsed time or inference.

[0047] When using ultrasound for contactless distance measurement for example a system out out combined ultrasound-reciever-/transciever-units is applicable. These units commonly measure elapsed time of ultrasound to one another and are continuously in contact to one another via transponder technologies. When using ultrasound it is also postulated for the whole object face to maintain intervisibility between the movable position measurement unit and the satellites. So it again makes sense to distribute a large number of satellites.

[0048] A further variant, as in claim 4, proposes the first measurement system to work according to an imaging method. In this variant the object face and/or the paint application device is recorded by imaging the same, for example by (IR-) cameras, contained in the satellites. Out of the recorded images the position of the paint application device as well as the geometry and color distribution of the object phase can be derived via a pattern recognotion machine. It can be helpful for the pattern recognotion machine to label single points of the object face and/or the paint application device, for example by previously placing landmarks with a characteristic contrast or geometry (for example crosses). Small (modulated or multiplexed) light- or heat sources as well as special reflectors or absorbers may serve as landmarks.

[0049] A further variant especially suited to aquire the position of the moved paint application device results when using movable cameras. These for example can be worn at the head of the operator in the direction of his view, whereby acquiring his manual working area continuously. Using three cameras fixed on a fix frame and a subsequent computational unit for feature extraction and localization for example the coordinates of arbitrary points in space within the visible range of the cameras may be determined. When acquiring by this ponts of the surface and additionally points of the paint application device, the position of the paint application device relative to the object face can be determined. The cameras may be supported by an additional

inertial measurement system being also fixed to the frame. The inertial system particulary allows to measure the dynamic movements of the head, which improves the tracking of destinctive points in the algorithm.

[0050] A further variant proposes an advancement according to claim 5. Accoring to this a laser beam emitted from one or more satellites is directed line by line or column by column over the working range, which comprizes the object face or parts thereof and/or the paint application device using a beam scanner. In a first sub-version the scattered light is detected by photo-sensors or cameras (herein after referred to as detectors), which are located within further satellites or together with the laser-source within a commen cabinet. The continuously received scattered light can be collocated to an image according to the scanning-prescript. Thus the method is about an imaging method, resulting, that all related information given above is applicable (also regarding marks etc.). If the detectors and the laser source are located within a common cabinet of a satellite it especially makes sense to utilize triple mirrows as marks, which retroreflect incident light back to the source.

[0051] In a further subvariant photoelectric transdurceers are located on the side of the paint application device directed towards the laser source or located at characteristic points of the object face in order to record the same. In these cases the crossing laser beam is detected photo-electrically and the positions are calculated from the known scannung reciept. This variant requires a highly precise common time base for all components.

[0052] The last variant, accoding to claim 6, finally is based on telemtry. To record the object face laser-supported, interferometric telemetric methods are suited, which conbine a laser source and a photo detector, whereby the emitted and the back-scattered laser beam are processed to aquire range information. Out of the know beam direction and the exact range information the shape of the object face can be determined.

[0053] A second measurement system, which serves for the purpose of independent navigation is proposed as in claim 7. Principally these systems are unable to determine an absolute position. Applicable are methods of velocity measurement, inertial navigation, the measurement of terrestrial properties like gravity (inclinometer) or the earth magnetic field (magnetometer) and the oriantation based on recording a small region of the object face.

[0054] The terrestrial measurands, inclination and north alignment, result in angular information. This is not sufficient for a navigation, but can add valuable information together with other navigation systems. Inertial navigation systems may comprize gyroscopes, which measure angular velocity, as well as rotational or linear acceleration sensors. The position of the paint application device is derived by one or two mathematical integration steps. The systems are able to track highly dynamic, even discontinous movements, but are getting unprecise over larger time periods or distances because because of a summing up of non-linearities and offset-drifts during integration.

[0055] The velocity can be measured relative to the object face by known methods, for example by measuring the rotational velocity of wheels, rolls or balls, which are in contact with the object face, or by contactless optical or acoustical methods of relative velocity easurement. By measuring the velocities at multiple points additional rotational velocity information can be gained.

[0056] Also the velocity sensors do not inherently provide sufficient accuracy and reliablilty. The position is also gained by Integration, which results in the above mentioned measurement inaccuracies. Furthermore slip in mechanical, rolling systems, as well as measurement drop outs in optical systems tamper the measurement results.

[0057] Recording the surface optically by photoelectric transducers (scanner,cameras etc.), which are directed towards the object face and a subsequent feature extraction can also provide position information. The recorded image can contain features of the already applied image, a reference pattern or constructional features like borders. The navigation based on those features is only sufficiently possible, if the features are rich in contrast. At large surfaces this may no be the case normally. There also is the danger of error propagation. An image scanner is, for example, very well suited to record unregularities of a border line, thus enabling with the help of a simple control mechanism a detailed paint application also on small propagating features at that border line, avoiding the adjoining wall to be colored unwillingly.

[0058] A quality improvement can be achieved when using optical sensors by evaluating the color value of the prime coat before and eventually after paint application and based on this by applying the amount of paint continuously and position dependent.

[0059] So there is a measurement system called second measurement system is attached with the paint application elements. It may contain the described sensors for measuring the velocity relative to the surface, further for measuring the inclination, the acceleration and/or rotational acceleration and or rotation rate, further for measureing the orientation in the earth's magnetic field, further to measure the position relative to the scattered color distribution of the ground layer.

[0060] According to the advancement in claim 9 also the object face can be recorded using the position measurement methods as described above. The recognition and digitizing of object faces and perturbations of the surface like doors, windows, protrusions, balconies, window sills, deposits eaves, arresters, switches, lamps and other accessoires defines the first operational step and may be carried out by a first measurement system, which works in the same way the navigation system works. In this step the color properties of the ground can be recorded electronically and utilized for a later color adjustment. Also the color quality of the ground may be evaluated and improved if necessary by repairing the plaster and adding a ground layer for example.

[0061] By this the geometry of the object face can be recorded by attaching at least two satellites, which contain transmitting and/or receiving components of a contactless distance or angular measurement system at fix positions of the object face. Also a further component of the first measurement system or the paint application device itself, which contain at least one transmitting or receiving component of the used contactless distance or angular measurement system, can be brought into contact with characteristic points of the object face to measure and store the position thereof.

[0062] According to the advancement in claim 10 the position of the application device is measured continuously. Preferably measurement data from the first and second measurement systems are used to continuously evaluate the position of the paint application elements.

[0063] According to the advancement in claim 11 the distance between application device and object face is adjustable. The distance of the paint application elements from the object face may be adjusted by an active control mechanism, which continuously measures the distance using distance sensors and controlls the position of the paint application elements perpendicular to the object face by using a control prescript and one or more servo motors.

[0064] When moving the paint application device on the object face it has to be secured, that the distance and direction of the paint application elements relative to the object face is maintained within a defined tolerance, which is determined by the properties of the paint application elements and of the paint application control. There are numerous technical solutions out of the state of the art like wheels, spheres, rolls, especially paint rolls, or gliding elements, which can secure to move the device linear, parallel and with a constant distance on the object face. If the treads comprize a certain size or elasticity small unevennesses of the object face can be compensated. In case of using slowly drying paints it is advantagous, if the paint application elements laterally protrude from the means to drive on the object face. Additionally an electronic or computer assisted control of the distance and the orientation of the paint application elements relative to the object face is possible, for example by using sensors to measure the distance at different points or by servo motors, which can control the position or inclination of the paint application head.

[0065] By using a suitable computer control for route planning all coordinates of the object face can be reached. Further a jib of a crane or a robotic manipulator being on a fix platform relative to the object face with the paint application device mounted on the outer end may be used to position the same. When using the mentioned manipulators the position and angle of the paint application device may be determined out of the position and angle of all elements of the manipulator. However, it has to be noted, that especially in case of large surfaces due to elasticities in such systems the position cannot be evaluated sufficiently accurate and it is highly recommended to utilize position measurement systems.

[0066] A further device according to the invention, which is freely movable on a facade, comprizes the components of the paint application device and is pressed against the surface by a low pressure suction mechanism. The device can either be controlled by a person using a remote control or autarkic with the help of a control unit, by driving over the not-yet painted reagions of the object face.

[0067] According to the advancement in claim 12 the movement of the application device is carried out mechanically. The device comprizes a handle and a person moves the device by pressing it against the object face. The work operation from an operators view is similar to the known painting with a paint brush or a paint roll. So operating the paint application device is carried out manually using a handle, by pressing it against the object face and moving it manually.

[0068] The alternative according to claim 13 proposes a semi-automatic operation of the paint application device. For an example built-in servo motors ensure a smooth motion. The opertor presses the device against the surface and follows the automatic motion. By this the application device is pressed against the surface and the motion velocity is determined by a motorized drive.

[0069] At last, as in claim 14, a fully automatic operation is possible. By this the motion of the paint application device is determined in a fully automatic way without the help of an operator. In this case the paint application device is kept and moved in an optimal distance and angle relative to the object face by using suitable devices,

whereby the route is determined based on the already painted regions. The paint application device may be pressed against the object face by a low pressure suction mechanism and the route may be predetermined by a control unit.

[0070] The advancement as in claim 15 proposes, that the paint application device comprizes nozzles, especially spray nozzles. These can be arranged, as in claim 16, in a row, especially in a matrix-arrangement.

[0071] So the paint is applied by using arrays of paint application elements, which are directed towards the object face. These comprize for example rows of paint spray nozzles arranged in parallell, whereby all paint spray nozzles of one row are designated for applying one color. It is advantagous, that the array of paint application elements laterally extends the contours of the paint application device. By this it can be worked easily in concave corners or slowly drying paint can be used, because the paint application elements laterally exceed also the position of the wheels by a measure, called overlap. Thus, when in a new step paint is applied beside a previously painted, still wet reagion, smearing is avoided. In case of multi-color printing the use of at least three multiple primary colors has been prooved in other application areas, like in painting of printing, wherby the primary colors are added in way, that arbitrary color values can be achieved.

[0072] There are multiple technological possibilities to realize paint nozzle arrays. The contained single paint nozzles can work according to different methods known from the state of the art. For example a compressed air spraying method, an airless-spraying method, a mixed air spraying method, the supercritical spraying method or the hot-melt method shall be mentioned. In more detail only an array of paint nozzles according to an airless-spraying method shall be described. The paint application of the individual paint nozzles is controlled by switching the paint supply by use of fast switching valves, which for example are contained within a valve block located within the paint feed. To get reproducable fluidic conditions the paint pressure at the input of the valves should be kept constant by a pressure control based on pressure sensing. Other variants require an additional compressed air supply.

[0073] Also Drop-On-Demand methods, where single droplets are produced and projected onto a surface, may be suited for use in the paint application device. Printheads according this function method are for example used within office printers. However, using these printheads for the paint application system according to the invention require redesigns of the printheads, because instead of a high resolution high droplet velocities and a high color rate is required. This can for example be realized by larger channel diameters and a higher power contribution during droplet acceleration.

[0074] Preferably fast drying paints are used for the paint application. If this is not possible, paints are to be preferred, which quickly cure when supplying heat, UV-radiation or an air flow. The paint application device therefore may contain devices at its bottom side for drying, curing and fixing like an UV-lamp, a fan or a heat radiator.

[0075] In a variant further layers may be applied additional to the color layer within one operation, for example a priming layer, which binds the color chemically. For this, paint application elements of the array may be used or further elements may be arranged in movement direction before or behind the paint nozzles. These may be designed equal to or different to the paint nozzles.

[0076] A base layer may be a wall paint layer for example, in which the color pigments are embedded during paint application.

[0077] A base layer may also be applied prior to the paint application as a complete paint layer. During paint application this layer will be partially dissolved by the paint thus embedding color particles into that layer. This opens the possibility to directly use dry color pigments when using suited application methods.

[0078] Embodimants of the paint application method accoring to the invention are depicted in the drawings:

[0079] Fig. 1 shows the paint application method schematically.

[0080] Fig. 2 shows the components of the paint application system 1 schematically. A computer control is connected with display and interface elements, with devices for paint application, with a first and second measurement system, whereby the first measurement system relies on distant points, which are (mit Absperrung)nted in satellites and the second measurement system contains components , which do not rely on far points, like image scanner, camera, inclination sensor, magnetometer, tachometer, distance sensor and an inertial system.

[0081] Fig. 3 shows a paint application head 24 of the paint application device 1, comprizing three rows of paint spray nozzles 20,21,22. The paint is supplied by fluid supplies 11.

[0082] Fig. 4 shows a paint application head 24 with additional paint application elements 23 to apply a primary layer or a cover layer. An optional UV-lamp 25 may serve for curing an applied paint layer.

[0083] Fig. 5 shows a first measurement system according to an angular measurement method. This comprizes within this embodiment two modulated light sources 5, which are for example LEDs being located on the paint application device 1. At fix positions of the object face 12 satellites of the first measurement system are attached by fixation means 19, each comprizing an optical lens 15 and the measurement element, a PSD 14. The embodiment also explains, how by using individually modulated light beams 17 and 18 the position of more than one light source can be determined and by this the inclination angle around the perpendicular axis of the wall also can be determined.

[0084] Fig. 6 shows a first measurement system according an imaging method, additionally supported by marks 26 on the paint application device 1 and at the object face 12. The marks 26 at the object face are attached to the same during recording the object face. Sketched is also the projected image of the object face 12 and the marks 26 on the camera chip.

[0085] Fig. 7 shows in detail a mark 26 for use at the object face. It is for example attached at a measurement point by a transparant substrate 28. There is a light source 5, for example a LED, in a well defined distance 29 to the object face. The distance is equal to the distance of a mark on the paint application device. So all marks of the object face and the paint application divice are within a plane.

[0086] Fig. 8 shows a first measurement system comprizing a laser scanner, comprizing a laser-source 32, a beam deflection unit 33 and an integrated photoelectric transducer 34. The laser beam is guided over the object face and the application device 1 according to a defined scanning prescript and the scattered light 31 is detected by the photoelectric transducer 34.

[0087] Fig. 9 shows a paint application device 1 with two rows of photoelectric transducers 35 for use in combination with the laser scanner according to Fig. 8. These detect the crossing laser beam and enable position detection of the paint application device out of known scanning prescipt.

[0088] Fig. 10 shows an operational scheme of the position evaluation using a first and a second measurement system.

[0089] Fig. 11 shows an embodiment of a paint application device 1 according to the method of the invention from a bottom view. This is suited for large surfaces. Sketched is an array of paint application elements, rolls 3 to move the paint application device and to maintain a constant distance between nozzles and surface, a handle 10, a supply 11 for physical or digital media transmission and two optical velocity sensors 7 as part of the second measurement system to measure relative velocity on the object face. Two light sources 5 as a part of the first measurement system, which works according to an angular measurement system, are sketched by dashed lines, since they are located on the top side of the paint application device 1. The array of paint applying elements 2 is designed as to laterally extent the dimensions of the rolls by a measure, the overlap 51. By this together with an appropriate operation also slowly drying paint can be used, because it can be avoided, that the rolls 3 are getting into contact with still wet, previously applied paint.

[0090] Fig. 12 shows an embodiment of the paint application device according to Fig. 11 from the side in a sectional view. Additional to Fig. 11 there can be seen the microcomputer 4 and an inertial measurement unit 6 as part of the second measurement system, which in this example together with velocity sensors 7 provides additional position information. The inertial measurement system for example comprizes an angular rate sensor to measure the angular velocity of the paint application device around the axis perpendicular to the wall, and an acceleration sensor to measure the acceleration in the direction of movement. A pressure sensor 53 allows the pressure in the paint supply being controlled.

[0091] Fig. 13 shows an embodiment of the paint application device 1 according to the method of the invention especially suited for repairs or touch ups. The device comprizes sliding elements 3 for moving on the the object face 12 and a paint appllication head 24, which especially at the lateral edges comprizes inclined nozzles 37. By this also in very concave corners and edges paint can be applied. An image scanner 38 being directed towards the object face enables to capture a part of the surface ground and by this to identify the position. Various display- and interface elements 36 allow to operate the device.

[0092] Fig. 14 shows an embodiment of the paint application device 1 comprizing an automatic control of the distance of the paint application elements from the object face and offering the option to apply a priming coat by an integrated paint roll 40. The device enables to apply the priming coat similar as usual, when using a paint roll. In the hub of the roll there is a coaxial servo motor 41, which is used to shift the part of the paint application device 1 containing the paint nozzles 2 in relation to the handle, which contains the media supply. In the position 42 only the priming coat is applied in the usual manner. After applying the priming coat at a certain point of the object face the part of the paint application device 1, which contains the paint nozzles 2 is rotated towards the object face by the servo motor and the distance between nozzles and object face is maintained constant by an active control with the help of range sensors 39. In the example the lateral dimensions of the paint application head exceed the rolls.

[0093] Fig. 15 shows a typical distance control für use in the embodiment of Fig. 14.

[0094] Fig. 16 explains the paint application onto an object face with the help a paint application device according to the embodiment of Fig. 14. The surface ground 45 is primed at the points 46, 44 by use of the paint roll of the application system. If the priming coat is satisfactory the paint application device is instructed by the operator to start paint application. During paint application the operator has to take care that the boundary of a previously painted region 47 is always within the overlap between the paint application head and the paint roll of the paint application device.

[0095] Fig. 17 shows an autonomous paint application device as a facade-system. For this the paint application device is suspended at a cable, which leads to a pulley thus enabling vertical motions. The pulley is moved at the top edge of the wall using a rail to enable horizantal motions.

[0096] Fig. 18 shows an autonomous paint application device comprizing a low pressure suction mechanism 50. This allows for a free motion, especially on large, vertical facades. From the position evaluation and the knowledge of the past route the paint application device automatically computes the route. To move on the object face preferably rolls are used, some of them beeing steerable.

<u>List of Symbols:</u>

1 Paint application device

2 Array of paint application elements

3 Roller/sliding devices

4 Microcomputer

5 Light source, heat source

6 Inertial measurement system as part of the second measurement system

7 Optical velocity sensor as part of the second measurement system

8 Paint reservoir

9 Battery

10 Handhold

11 Fluidsupply

12 Surfaceof the object

13 Satellite of the first measurement system

14 Position sensing device (PSD) or camera

15 Optical lens

16 Obstacle, disturbance

17 Beam of modulated light 1

18 Beam of modulated light 2

19 Fixation

20 Paint nozzle for a first basic color

21 Paint nozzle for a second basic color

22 Paint nozzle for a third basic color

23 Paint application elements for applying a ground layer or finishing layer

24 Paint application head

25 UV-light source for layer curing

26 Landmark

27 Camera chip, projected image

28 Substrate, transparent

29 Reference distance

30 Emitted laser beam

31 Scattered beam

32 Laser source

33 Beam deflection unit

34 photoelectric transducer

35 Retroreflecting Landmark or photoelectric transducer array

36 Display, user interface

37 Paint application head, inclined

38 Image scanner

39 Distance sensor

40 Paint roll

41 Coaxial servo motor

42 Position for applying base coat

43 Handle including media supply

44 Fresh base coat

45 Original surface

46 Base coat

47 Decorative paint coat

48 Horizontal rail

49 Vehicle comprizing a pulley, an integrated drive, and a system control

50 Low pressure suction mechanism

51 Overlap

52 Valve block

53 Pressure sensor

Claims:

1. Method for applying paints or varnishes in order to apply a color design on surfaces of buildings or public or civil engineering works, c h a r a c t e r i z e d i n,

that first the object face is recorded as a digital object and a record is defined,

that next a template of the design object to be applied is implemented within the record of the digital object and

that finally with the record obtained thereof a movable paint application device is controlled to apply the paint or the varnish.

2. Method according to the preceeding claim, c h a r a c t e r i z e d i n, that to measure the position of the application device a method from the distance and/or angle measurement technology, from telemetry or from imaging measurement technology is applied, which relys on far points and measures positions and/or color values in relation to said far points.

3. Method according to claim 2, c h a r a c t e r i z e d i n, that the measurement method is based on the contactless measurement of distance and/or angles.

4. Method according to claim 2, c h a r a c t e r i z e d i n, that the measurement method is based on an imaging method.

5. Method according to claim 2, c h a r a c t e r i z e d i n, that the measurement method is based on laser-scanning.

6. Method according to claim 2, c h a r a c t e r i z e d i n, that the measurement method is based on telemetry.

7. Method according to one of the preceeding claims, c h a r a c t e r i z e d i n, that for the measurement of the position of the paint application device a method without the help of fix far points is used.

8. Method according to one of the preceeding claims, c h a r a c t e r i z e d by the combination of at least one position measurement system, that relies on far points and at least one position measurement system, that does not rely on far points.

9. Method according to claim 1, c h a r a c t e r i z e d i n, that to record the object face one or more methods are applied, which work according to position measurement methods according to one of the claims 2 to 8.

10. Method according to one of the preceeding claims, c h a r a c t e r i z e d i n, that the position of the application device is measured continuously.

11. Method according to one of the preceeding claims, c h a r a c t e r i z e d i n, that the distance between the nozzles of the application device and the object face is adjustable.

12. Method according to one of the preceeding claims, c h a r a c t e r i z e d i n, that the motion of the application device is carried out manually.

13. Method according to one of the preceeding claims, c h a r a c t e r i z e d i n, that the motion of the application device is carried out semiautomatic.

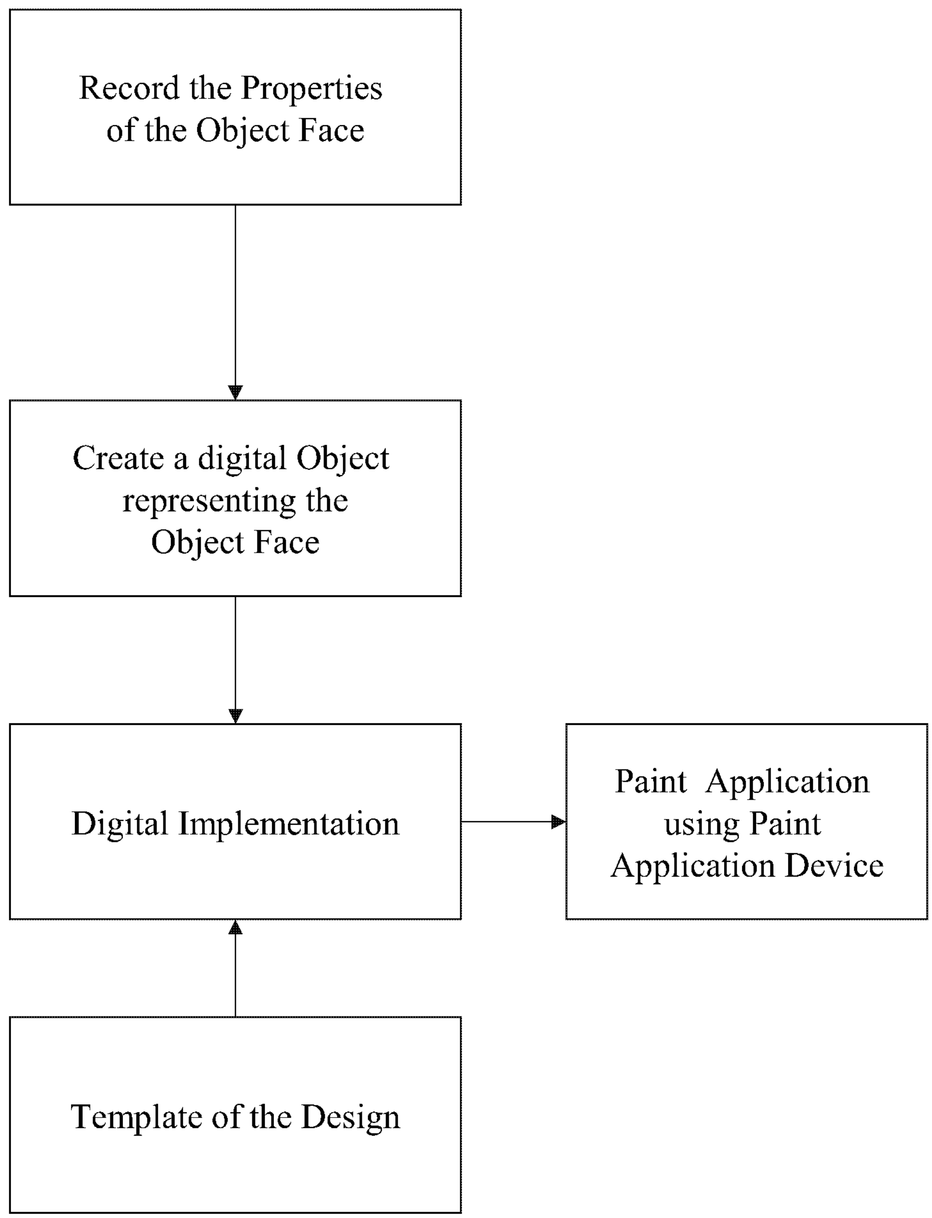
14. Method according to one of the preceeding claims, c h a r a c t e r i z e d i n, that the motion of the application device is carried out fully automatic.

15. Method according to one of the preceeding claims, c h a r a c t e r i z e d i n, that the application device comprizes at least one nozzle, especially a spray nozzle.

16. Method according to one of the preceeding claims, c h a r a c t e r i z e d i n, that the application device comprizes a row, especially a matrix arrangement of nozzles.

Abstract:

A method for applying paints or varnishes in order to apply a color design on surfaces of buildings or public or civil engineering works, comprizes in a first step, that the object face is recorded as a digital object and a record is defined. Next a template of the design object to be applied is implemented within the record of the digital object. Finally with the record obtained thereof a movable paint application device is controlled to apply the paint or the varnish.



Record the Properties of the Object Face
Create a digital Object representing the Object Face
Digital Implementation
Paint Application using Paint Application Device
Template of the Design

FIG. 1

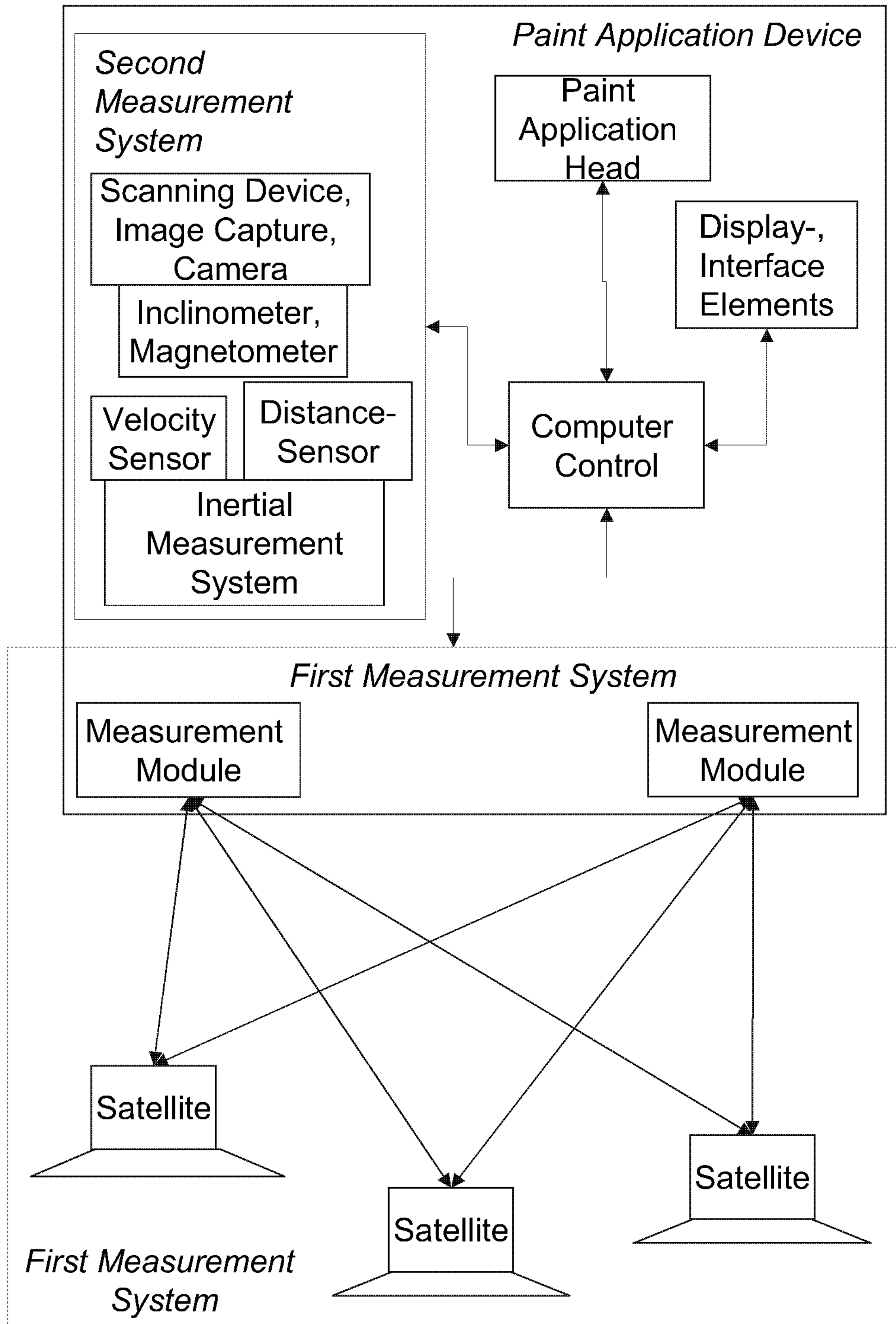

Paint Application Device
Second Measurement System
Scanning Device, Image Capture, Camera
Inclinometer, Magnetometer
Velocity Sensor
Distance-Sensor
Inertial Measurement System
Paint Application Head
Display-, Interface Elements
Computer Control
First Measurement System
Measurement Module
Measurement Module
Satellite
Satellite
Satellite
First Measurement System

FIG. 2

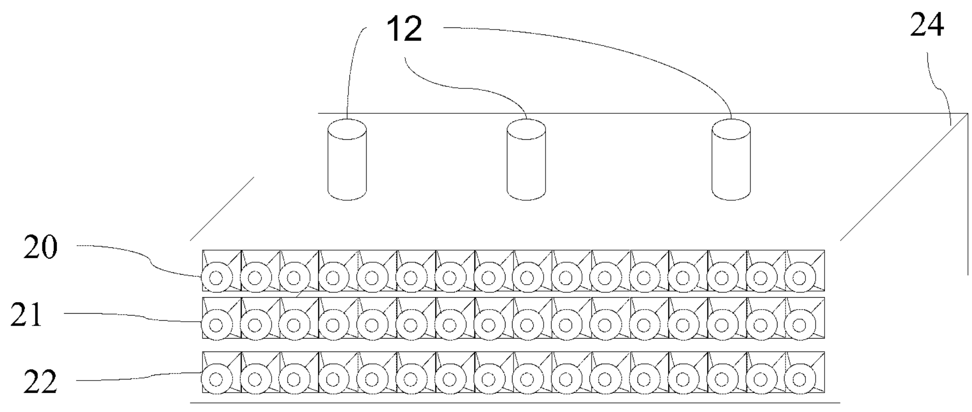


FIG. 3

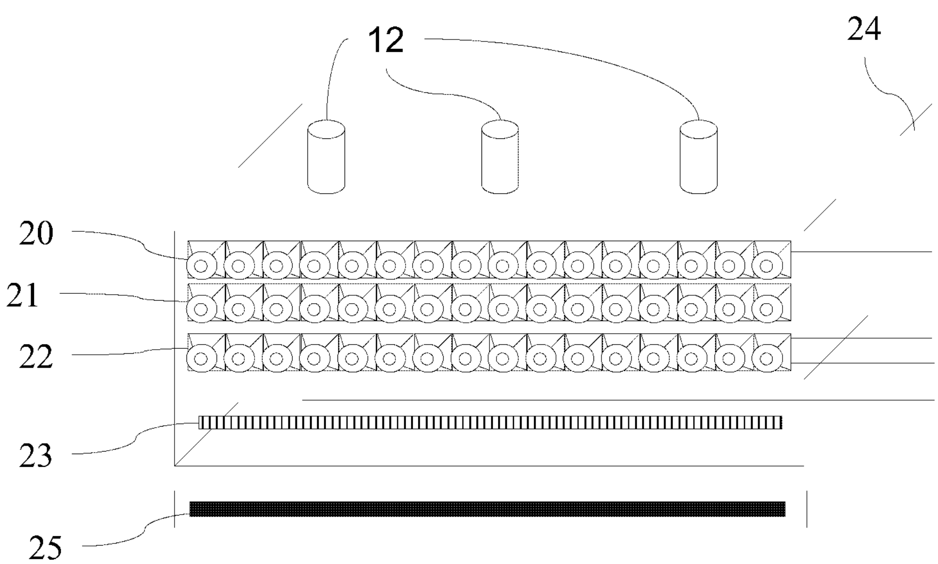


FIG. 4

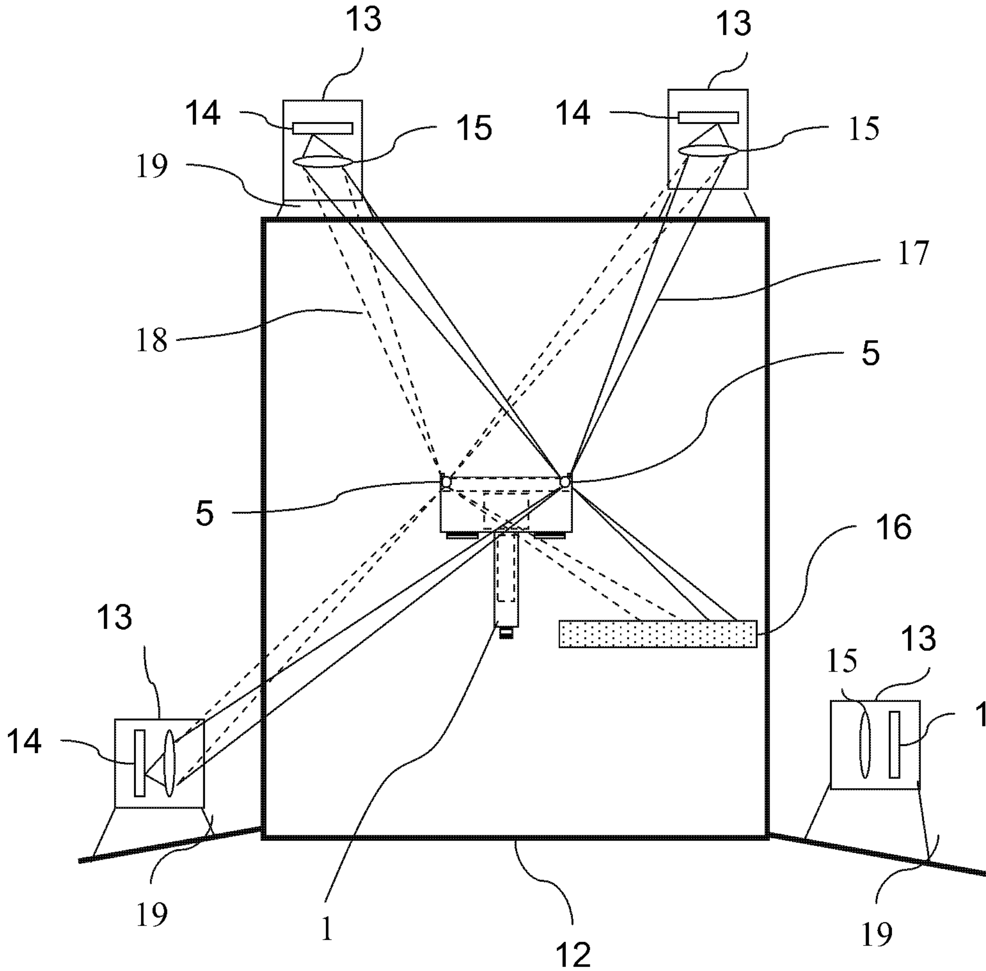


FIG. 5

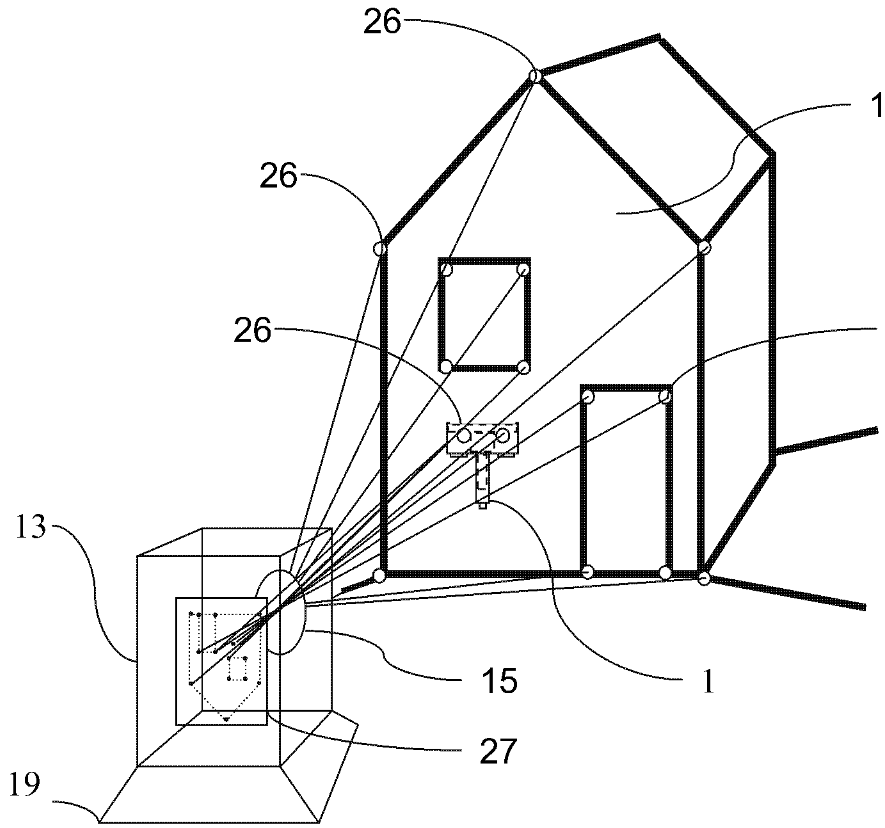


FIG. 6

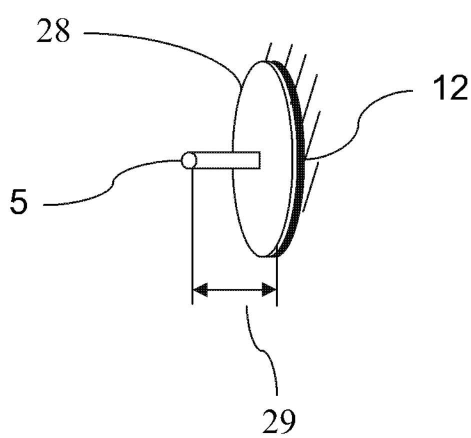
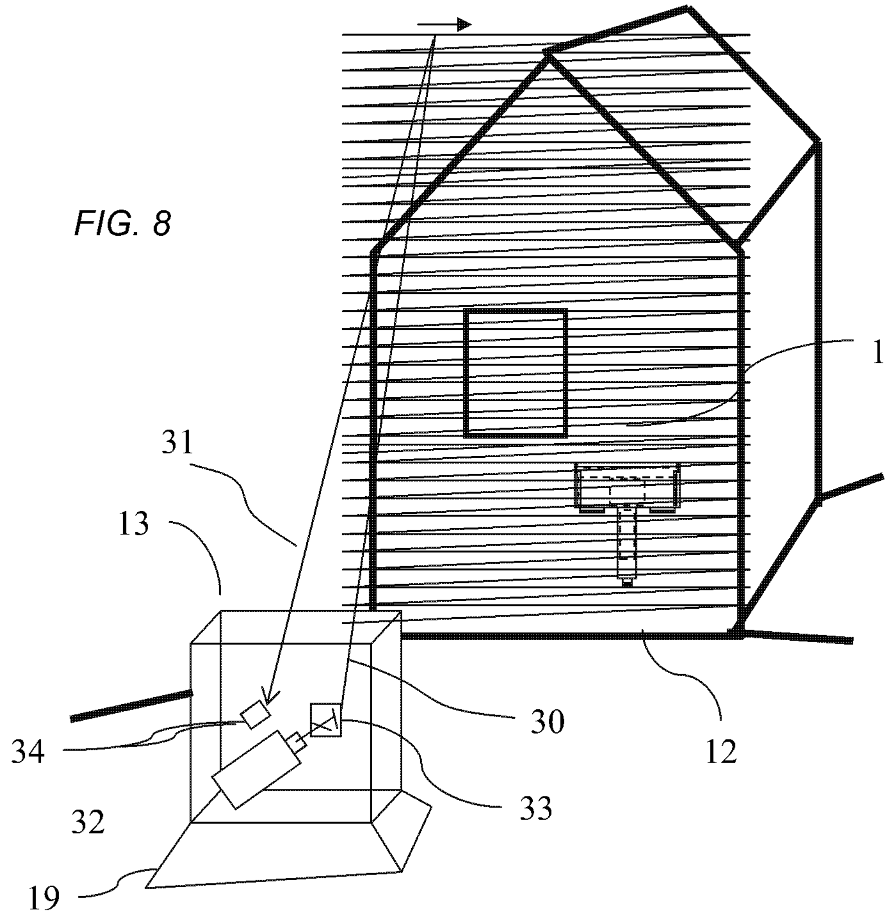


FIG. 7

FIG. 8



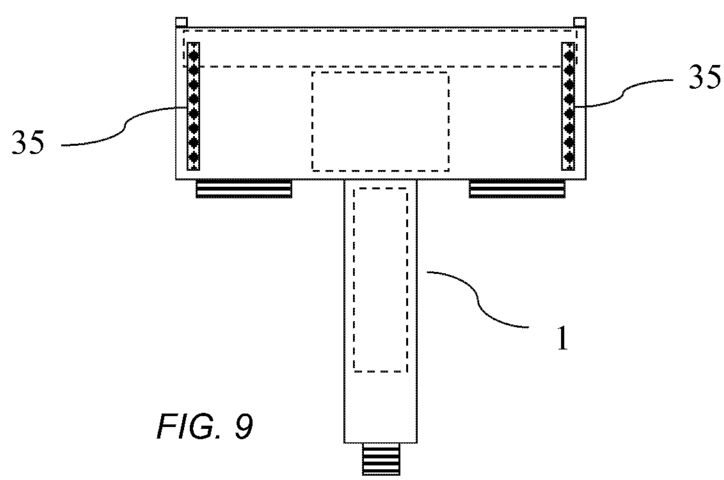


FIG. 9

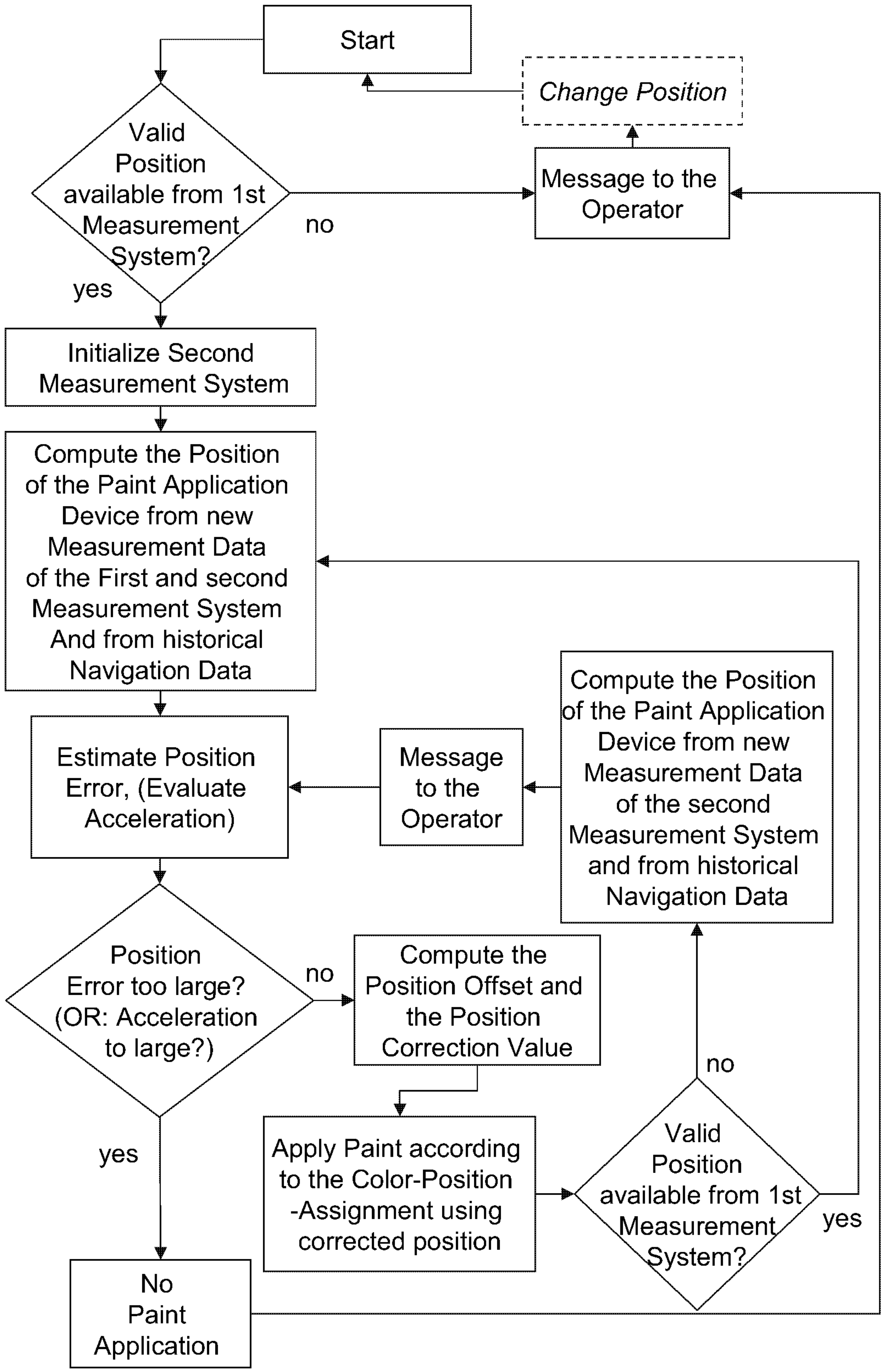

Start
Change Position
Valid Position available from 1st Measurement System?
no
yes
Message to the Operator
Initialize Second Measurement System
Compute the Position of the Paint Application Device from new Measurement Data of the First and second Measurement System And from historical Navigation Data
Estimate Position Error, (Evaluate Acceleration)
Message to the Operator
Compute the Position of the Paint Application Device from new Measurement Data of the second Measurement System and from historical Navigation Data
Position Error too large? (OR: Acceleration to large?)
no
Compute the Position Offset and the Position Correction Value
no
yes
Apply Paint according to the Color-Position -Assignment using corrected position
Valid Position available from 1st Measurement System?
yes
No Paint Application

FIG. 10

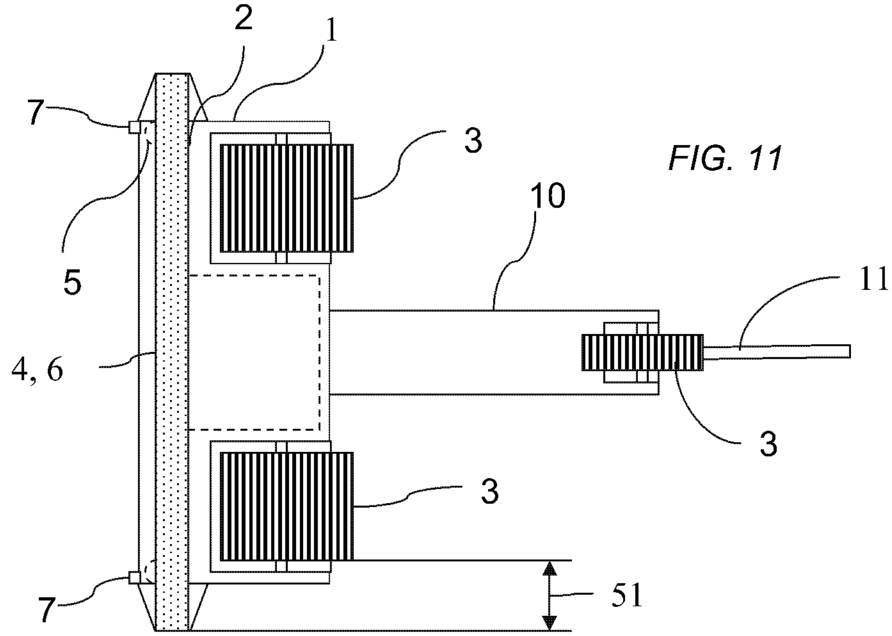


FIG. 11

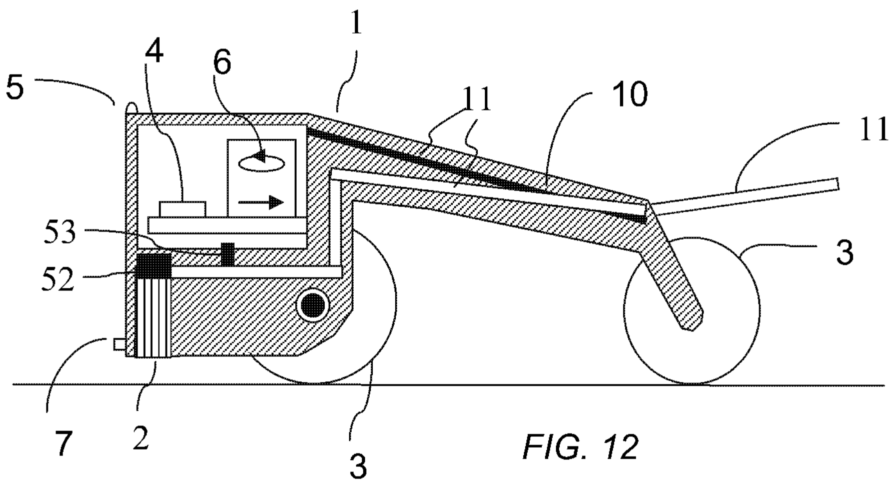


FIG. 12

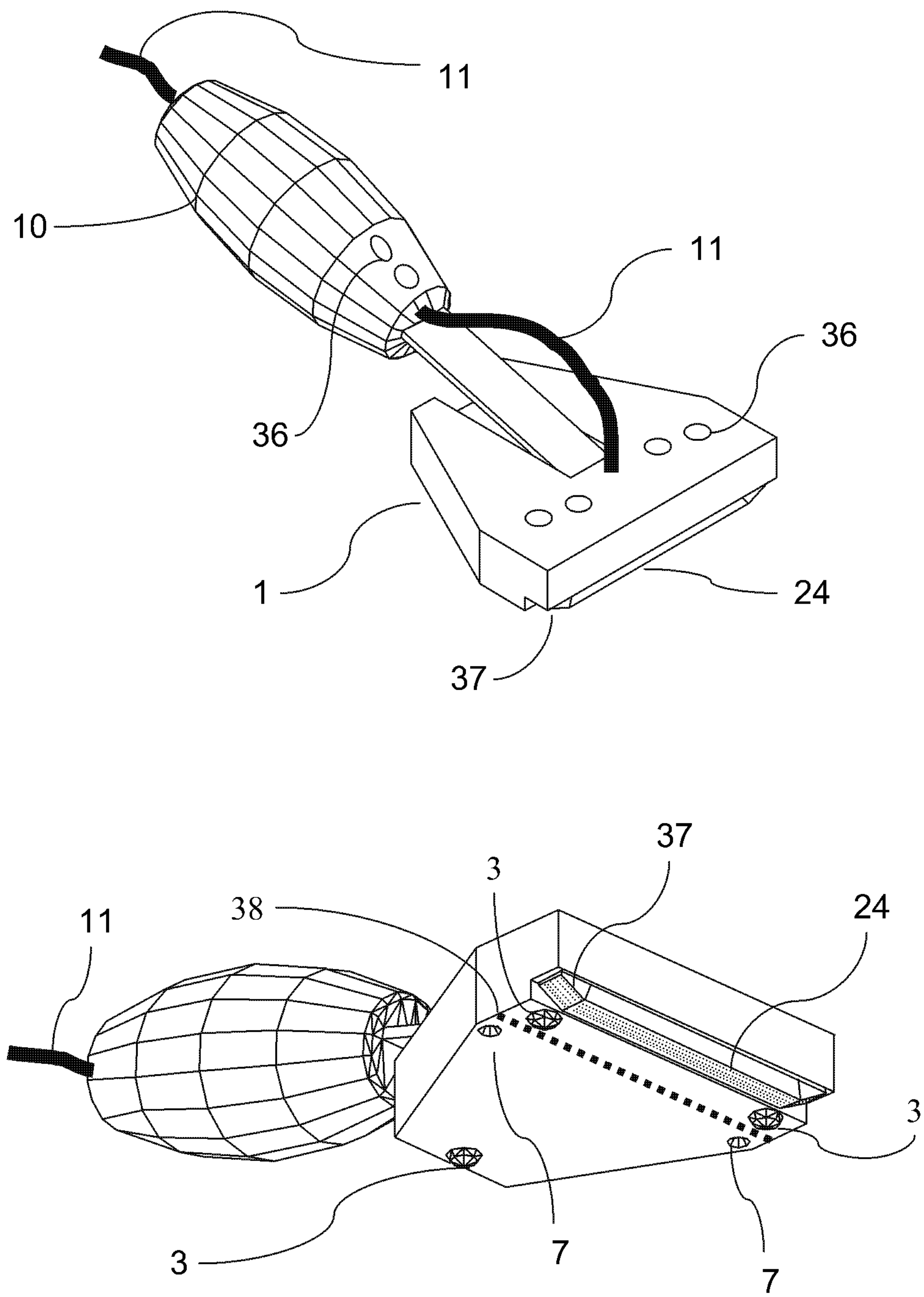


FIG. 13

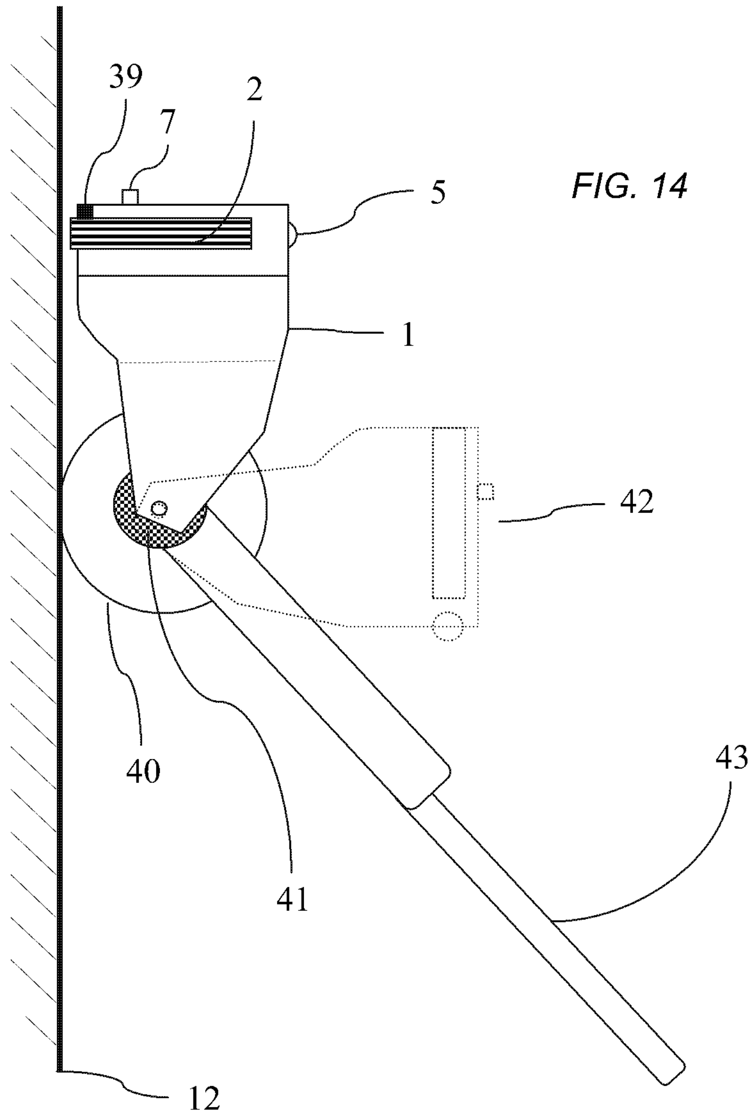

39
7
2
5
1
42
40
41
43
12

FIG. 14

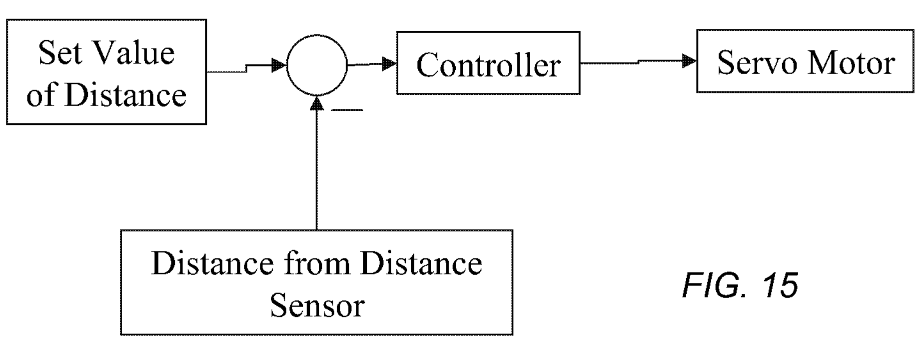

Set Value of Distance
Controller
Servo Motor
Distance from Distance Sensor

FIG. 15

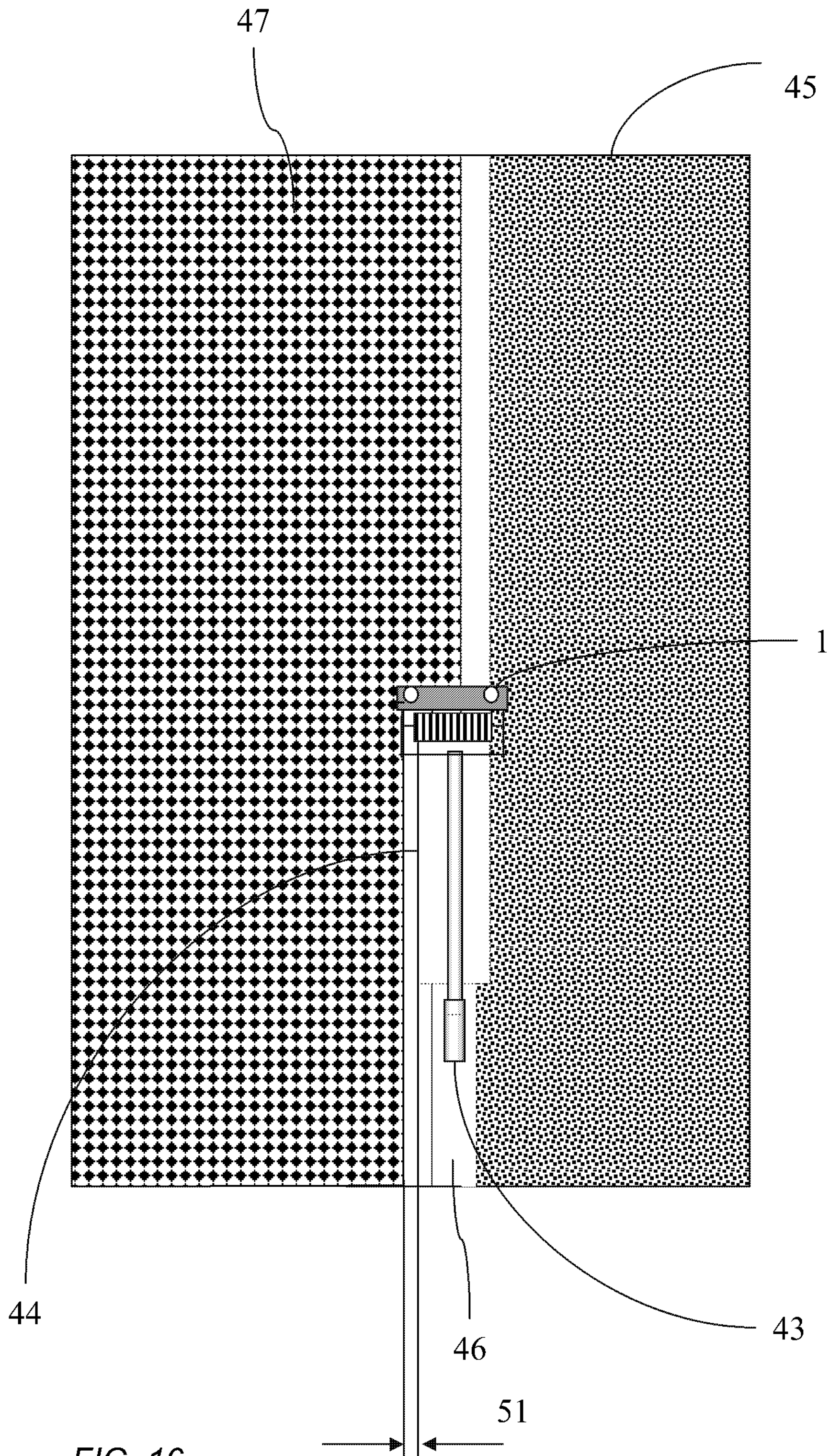


FIG. 16

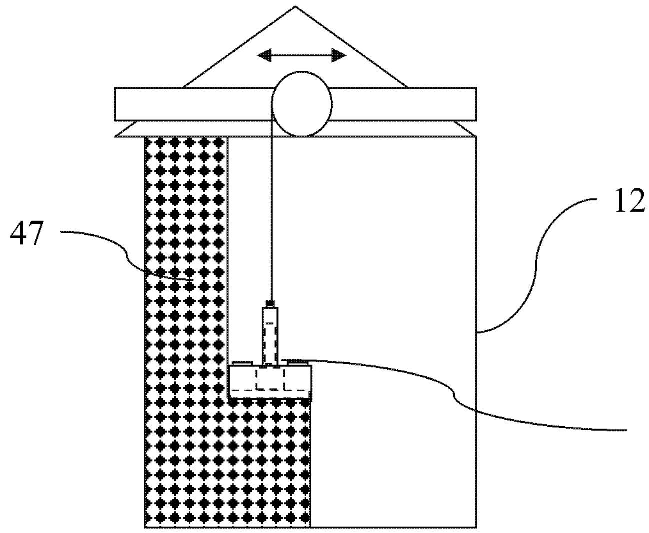


FIG. 17

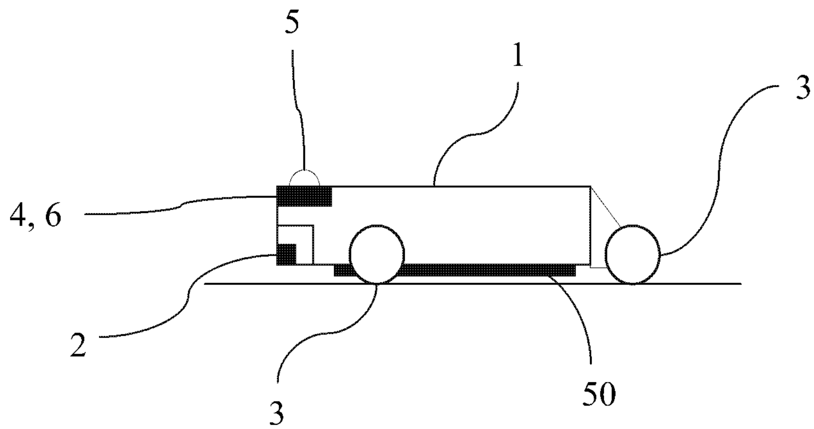


FIG. 18